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***Staurophora ouiangaensis spec.nov.* (Bacillariophyceae, Anomoeoneidaceae), a new  
diatom from the Ounianga Lakes in the Sahara, Chad**

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## Abstract

Modern diatom assemblages were investigated in the Ounianga Lakes located in the driest part of the Chadian Sahara. These lakes still exist today due to groundwater seepage. They contain a variety of diatom species, one of which has never been identified. Here we described a new species of *Staurophora*, *Staurophora ouniangaensis* sp. nov. based on detailed light and scanning electron microscopy observations. The new taxon presents all morphological characters attributed to this genus and differs from other *Staurophora* species mainly by its specific valve outline and the slightly twisted frustules along the transapical axis. Comparison is made with the morphologically resembling *Cymbella obtusa* which was reported from Chad. This taxon has a much coarser stria density than the here new described *Staurophora* species. *Staurophora ouniangaensis* sp. nov. confirms that *Staurophora* species prefer inland saline environments. Indeed, in the Ounianga lakes, *Staurophora ouniangaensis* was preferentially observed in mesosaline to hypersaline waters.

**Key words:** Africa, *Cymbella obtusa*, mesosaline waters, new species, taxonomy

## Introduction

The lakes of Ounianga are a UNESCO World Heritage Site (UNESCO 2015) and form a unique hydrological system in the world (Kröpelin 2007). This exceptional value comes from the existence of a series of lakes and oases in the Chadian Sahara, one of the most arid part of the world. Featuring peculiar geological structures—Nubian Sandstone—the different types of landscape have undoubted beauty (Figure 1).

Their current diatom communities have not yet been the subject of extensive studies. Two earlier studies (Round 1961a, b) were carried out on a few samples from the Chadian Sahara, the Ennedi and some of the Ounianga lakes, and listed the main diatom species observed in these environments. More recently, Kröpelin et al. (2008) studied climate changes in the Sahara during the last 6,000 years, including a salinity reconstruction, based on the African diatom database (Gasse *et al.* 1995) and modern diatom assemblages in the lakes of Ounianga. During the wet mid-Holocene period, the fossil diatom flora was characterized by the significant abundance of freshwater species (mainly *Aulacoseira* Thwaites (1848: 167) and *Synedra* Ehrenberg (1830: 40) s.l.). An increase in salinity ( $300 \mu\text{S}\cdot\text{cm}^{-1}$  to  $500 \mu\text{S}\cdot\text{cm}^{-1}$ ) occurred between 4,200 and 3,900 years B.P. (Kröpelin et al. 2008) and favoured the development of salt tolerant diatoms such as *Nitzschia fonticola* (Grunow) Grunow (in Van Heurck 1881: pl. 69, figs 15-20), *N. cf. elliptica* Hustedt (1949: 148), *Rhopalodia gibberula* (Ehrenberg) O.Müller (1899: 97) and *Stauroneis* Ehrenberg (1843: 45) at the expense of *Aulacoseira* species. A recent study conducted in each lake of the Ounianga system by Rirongarti (2019) and Rirongarti *et al.* (submitted) revealed many more species than previously listed (Round 1961a, b, Kröpelin et al. 2008), including some *Staurophora* Mereschkowsky (1903: 45, 142) taxa.

The genus *Staurophora* is a small entity consisting of only fifteen species and one accepted variety (Guiry in Guiry & Guiry 2020). In addition, the taxonomic status of *S. gregoryi* Mereschkowsky (1903: 22) and *S. vilamae* Maidana, Seeligmann & Morales (2009: 269) is uncertain (Guiry in Guiry & Guiry 2020). *Staurophora* species are characterised by linear or lanceolate valves, a gently curved valve face merging

sometimes steeply into the mantle, a central area expanded in a fascia reaching the margins with 2 to 3 shortened striae, and one single chloroplast (Round et al. 1990). Most of the species are found epipelagic in marine and brackish waters. However, some taxa such as *Staurophora caljonii* Cocquyt (Cocquyt 2004: 40) are reported from inland waters with elevated conductivities.

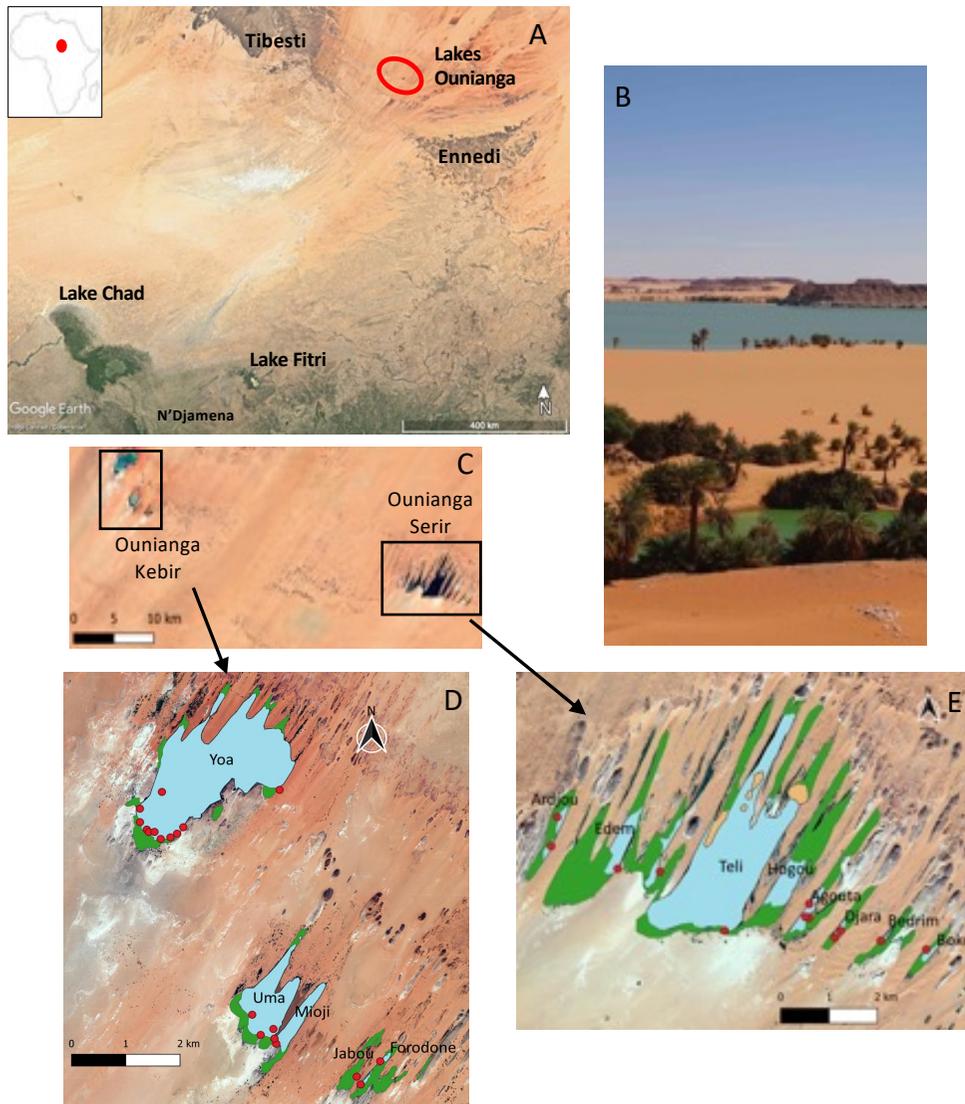
### **Sampling sites**

The region of Ounianga, located between 19°N and 20°E, is one of the most arid parts of the Chadian Sahara (Figure 1A). Situated between the volcanic ranges of Tibesti and Ennedi and is backed by the sandstone plateaus of the Erdos, it is characterized by a hyper arid Saharan climate marked by long periods of drought and practically no rain. Average precipitation recorded in the 1960s was less than 5 mm per year while potential evaporation was around 6 m per year (Capot-Rey 1961).

The particularity of this region of northeastern Chad is the presence of splendid lake complexes located in narrow sandstone escarpments formed by the wind (Figure 1E). These lake complexes, considered to be the largest lake system in the Sahara, are divided into two groups (Figure 1C). To the west, at 19.055°N and 20.505°E, the group of Ounianga Kebir consists of Lakes Yoa, Uma, Mioji, Jabou and Forodone (Figure 1D). Fifty kilometers to the east, at 18.929°N and 20.850°E, the group of Ounianga Serir is aligned in a north-east/south-west direction in a depression thought to be of aeolian origin. The Ounianga Serir group consists of Lakes Ardjou, Edem, Teli, Hogou, Agouta, Djara, Bedrim and Bokou, aligned parallel to each other and separated by sand dunes (Figure 1E). They spread on about 10 km. All these lakes are currently fed by the fossil waters of the Nubian Sandstone Aquifer System (NSAS), which enable the lakes to persist under arid climate (Kröpelin 2007, Poulin 2018).

The geomorphological configuration means that the lakes of Ounianga Kebir are all strongly saline, with conductivities ranging from 64,000  $\mu\text{S}\cdot\text{cm}^{-1}$  to 352,000  $\mu\text{S}\cdot\text{cm}^{-1}$ , whereas the spring water that feeds them is fresher (217  $\mu\text{S}\cdot\text{cm}^{-1}$  and 623  $\mu\text{S}\cdot\text{cm}^{-1}$ ). Lake Yoa is the largest and deepest Ounianga Kebir lake with an area of 3.58 km<sup>2</sup> and a maximum depth of 27 m. Furthermore, it never dried out for the last 6,000 years (Kröpelin et al. 2008).

The Ounianga Serir lakes are located in a 10 km-wide depression and display a specific hydrological functioning because of their parallel alignment and their 'staircase' position at different elevations. The topography allows that lake water can flow through sand dunes from one lake into the other. Consequently, water becomes gradually more saline as it reaches the central Lake Teli which is located at the lowest point of the depression (Poulin 2018). The mechanism results in an increasing salinity gradient from the peripheral to the central lakes: from Lake Bokou in the east (326  $\mu\text{S}\cdot\text{cm}^{-1}$ ) and Lake Ardjou in the west (2880  $\mu\text{S}\cdot\text{cm}^{-1}$ ) to the central extremely saline Lake Teli (112,100  $\mu\text{S}\cdot\text{cm}^{-1}$ ). The intense evaporation affecting the large (4.36 km<sup>2</sup>) and shallow (maximum depth of 5 m) Lake Teli is compensated by groundwater input from the NSAS and by a steady flow from the neighbouring lakes through the dunes (Poulin, 2018). Thus the water level in the lakes is constant throughout the year (Van der Meeren et al. 2019). Numerous springs are present on the shores of the lakes which are partially or totally covered with macrophyte vegetation.



**Figure 1.** Location of Ounianga lakes district and studied area. A. Locations Lakes Ounianga in Chad. B. Picture of Lake Yoa (December 2016, @ F. Sylvestre). C. Location of the two groups of lakes. D. The lakes of Ounianga Kebir and location of studied sites (red dots). E. The lakes of Ounianga Serir and location of studied sites (red dots). Drawings based on satellite images (Google Earth Pro 2021).

## Material and methods

Samples from the Ounianga lakes for diatom investigation were collected during two field trips, in December 2015 and December 2016. For each sampling site, the water-sediment interface was collected using a sediment grab-sampler (Ponar, Rickly Hydrological Co.). Planktonic diatoms were collected with a phytoplankton net of 5  $\mu\text{m}$  mesh while epyphytic species were scraped off submerged parts of macrophytes. All samples were preserved with ethanol. Physico-chemical parameters were measured *in situ* and major ionic composition was determined in the laboratory at CEREGE (Aix-en-Provence, France) (Table 1). In total, twenty-six samples were collected at Ounianga Kebir and seventeen samples at Ounianga Serir.

The preparation of permanent microscopic slides for diatom analyses was carried out at the Laboratoire Préparation Micropaléontologie at CEREGE in Aix-en-Provence (France). Water and surface sediments were successively treated with hot hydrochloric acid and hydrogen peroxide. After several rinsing/decanting periods with distilled water, an aliquot of the cleaned material was mounted in Naphrax to obtain permanent slides for light microscopy (LM). In CEREGE, diatom observations were done with a Nikon 80i light microscope, equipped with Differential Interference Contrast (Normarski) and an Optiflex digital camera, using a 100x immersion oil objective. Additionally, at Meise Botanic Garden (Belgium), diatoms slides were observed with an Olympus BX 51 microscope, equipped with Differential Interference Contrast (Normarski) and an Olympus UC30 digital camera, using an 100x oil immersion objective.

For scanning electron microscopy (SEM), aliquots of the oxidized material were mounted on aluminium stubs, air-dried and sputter-coated with 50 nm of gold (Balzers Union SCD 020). The stubs were studied at the Meise Botanic Garden with a Jeol JSM-7100FLV Field Emission Scanning Electron Microscope operating at 1 kV and 6.9 mm working distance.

**TABLE 1.** Studied samples in which *Staurophora ouniangaensis sp. nov.* was observed, with sample name and type of sample (M: macrophytes, S: surface sediment), location (latitude, longitude), month/year of sampling, physical parameters measured in the field (conductivity in  $\mu\text{S}\cdot\text{cm}^{-1}$ , pH, and lake water temperature in  $^{\circ}\text{C}$ ) and chemical parameters analysed in the laboratory (alkalinity, major ions)

Lake	Yoa		Mioji	Jabou	Teli	Agouta		Djara	Bedrim	Bokou
Sample name (sample type)	Yoa-A1m (M)	YOl2-16(S) YOl3-16(S)	Mioj-Bm (M) Mioj-Cm (M) MJl1-16 (S) MJl2-16 (S) MJl3-16 (S)	JABl1-16 (S) JABl2-16 (S)	TL1-16 (S)	Agou-Bm (M)	AGl1-15 (S)	DJl1-16 (S)	Bed-Bm(M)	Bok-Bm (M)
Latitude (°N)	19.047562	19.047562	19.01072	19.00425	18.91893	18.921258	18.921258	18.917662	18.91709	18.91546
Longitude (°E)	20.492858	20.492858	20.51639	20.53079	20.87196	20.88858	20.88858	20.89364	20.90261	20.91156
Month/Year sampling	12/2016	12/2015	12/2016	12/2016	12/2015	12/2016	12/2016	12/2016	12/2016	12/2016
Alkalinity (mol.L <sup>-1</sup> )	84	48800	25956	118177	46726	62	1013	71	29	126
Cl (mg.L <sup>-1</sup> )	47	9656	21557	105867	23817	250	2221	126	65	12
SO <sub>4</sub> (mg.L <sup>-1</sup> )	37	15744	10606	79075	12750	129	142	4	63	27
Ca (mg.L <sup>-1</sup> )	11	159	231	159	159	30	37	26	43	44
Mg (mg.L <sup>-1</sup> )	5	19	19	19	19	69	47	48	15	6
Na (mg.L <sup>-1</sup> )	50	22425	29467	140192	34500	209	202	127	60	12
K (mg.L <sup>-1</sup> )	4	3186	2899	25935	10920	46	47	32	10	2
Conductivity (μS·cm <sup>-1</sup> )	344	64900	124000	82700	105100	1807	1833	1343	737	326
pH	6.98	10.11	9.03	8.2	10.2	8.33	8.1	7.97	8.03	7.77
Temperature (°C)	31.2	26.6	23.76	30.84	25	23.6	17.4	23.1	24	23.3

## Results

Division **Bacillariophyta**

Class **Bacillariophyceae**

Subclass **Bacillariophycidae**

Order **Cymbellales**

Family **Anomoeoneidaceae**

Genus **Staurophora**

*Staurophora ouiangaensis* Rirongarti, Cocquyt, Paillès & Sylvestre *spec. nov.* (Figs 2–31)

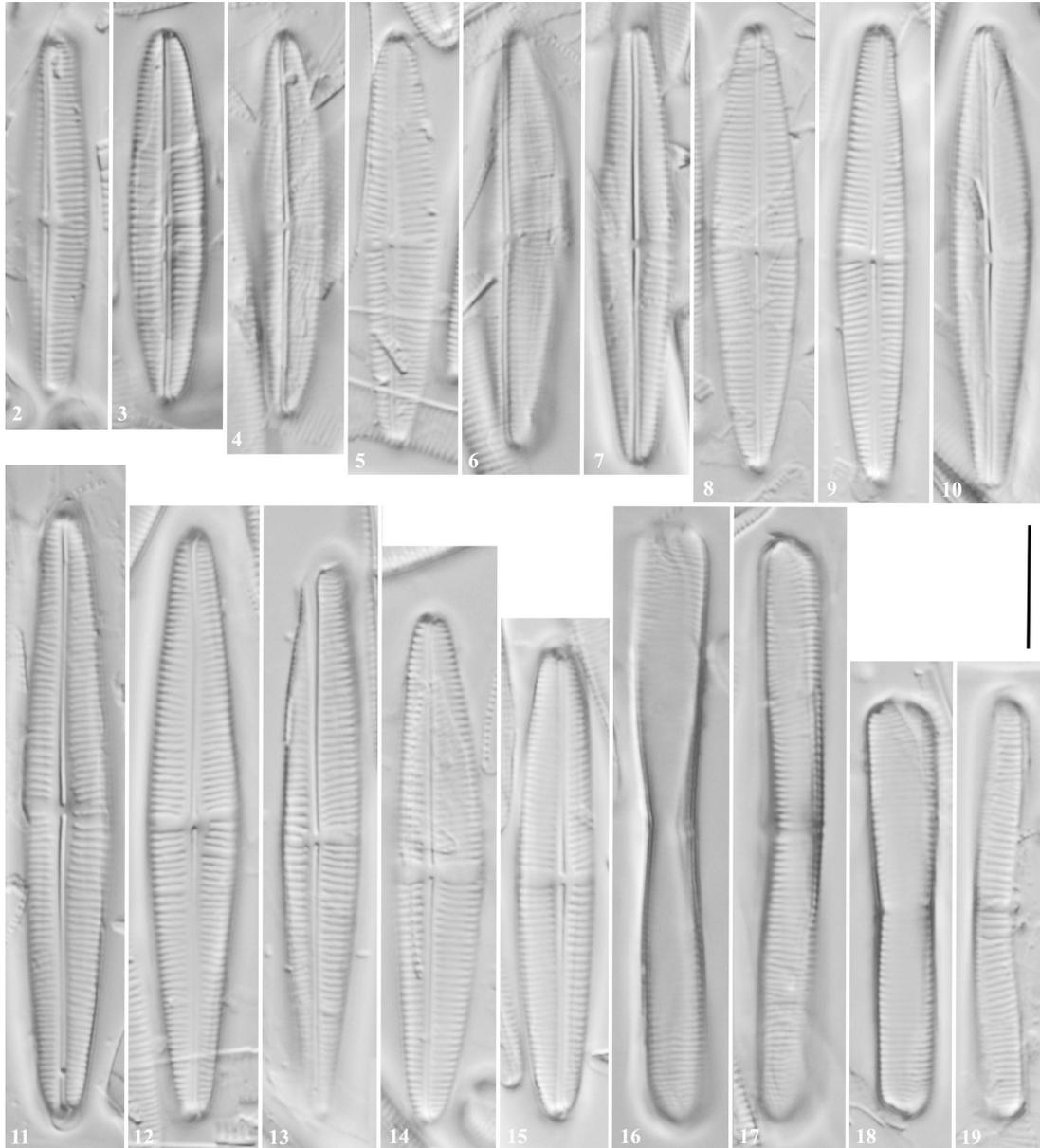
Frustules slightly constricted mid-valve and weakly twisted along the transapical axis. Valves lanceolate with slightly rostrate apices, length 20.5–59.5  $\mu\text{m}$  ( $n = 100$ ), width: 4.3–8.6 (10.5)  $\mu\text{m}$  ( $n = 70$ ). Axial area narrow becoming somewhat wider towards the middle of the valve. Central area variable, asymmetric, expanded to the edge of the valve face and valve mantle on the secondary side. On the primary side, the central area can be absent with a single median stria more widely spaced, or can be present and then of variable width with one to three shortened striae of variable length and more widely spaced than the other striae. Raphe straight, filiform with weakly enlarged central raphe endings and deflected terminal raphe endings to the same direction (primary side). Striae weakly radiate, becoming convergent towards the poles; about (15) 16–19 striae (mean of 17) in 10  $\mu\text{m}$  near the central area, and (17) 18–24 striae (mean of 20) towards the poles.

**Type:** —CHAD. Borkou-Ennedi-Tibesti Region (BET): Ounianga Sérir, Lake Jabou, 19.00425°N, 20.53079°E, December 2016 (holotype BR!4635, Meise Botanic Garden, Belgium, the valve representing the holotype is here illustrated in Fig. 11).

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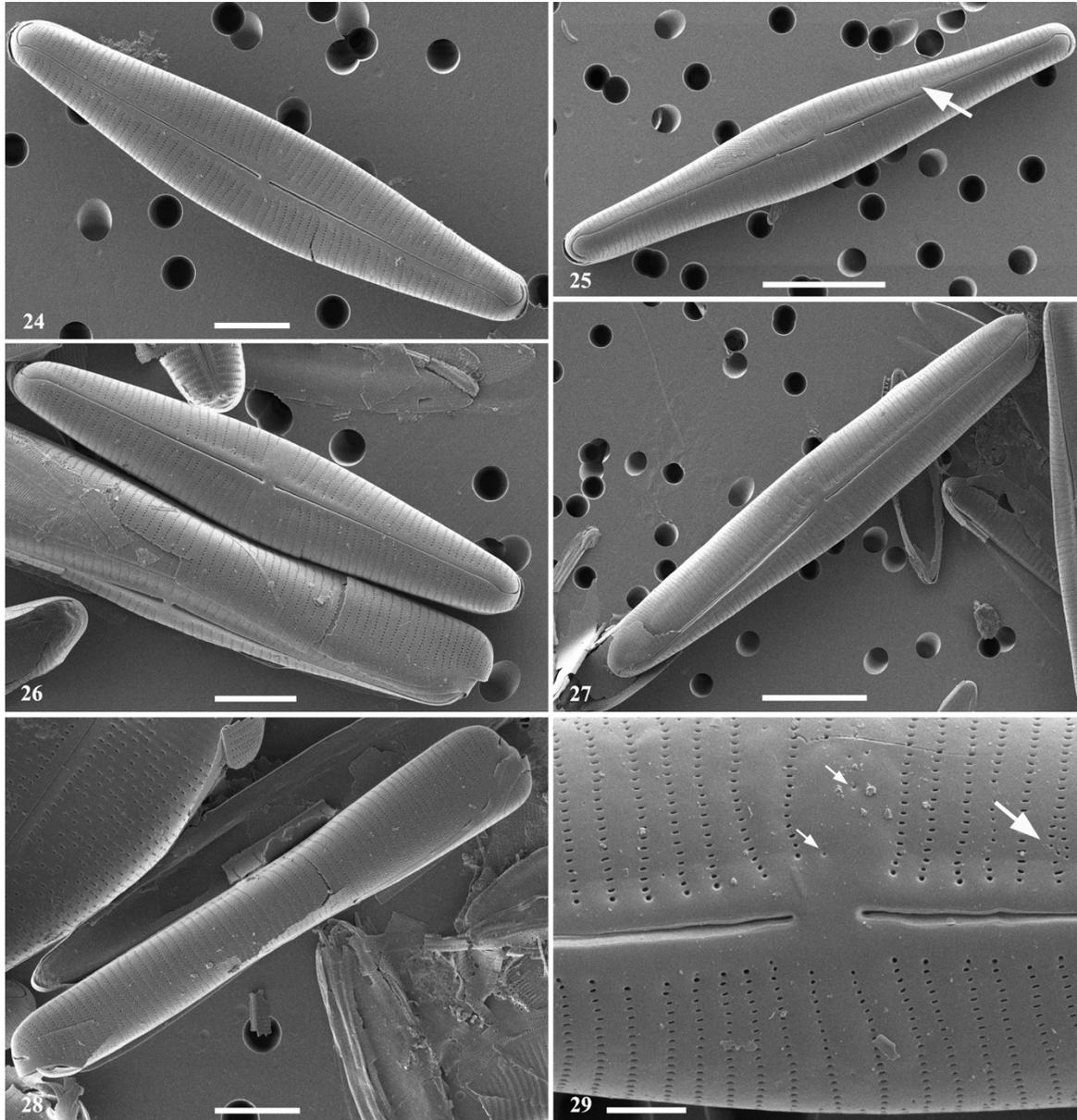
**Ethymology:** —The specific epithet “ouiangaensis” refers to the region of Ounianga, where the new species was first observed.

**Ecology and distribution:** —This taxon was represented in Lakes Yoa, Mioji, Jabou, Teli, Agouta, Djara, Bedrim and Bokou. The conductivity in these lakes varies from 326 to 124,000  $\mu\text{S}\cdot\text{cm}^{-1}$  and the pH from 6.98 to 10.2.



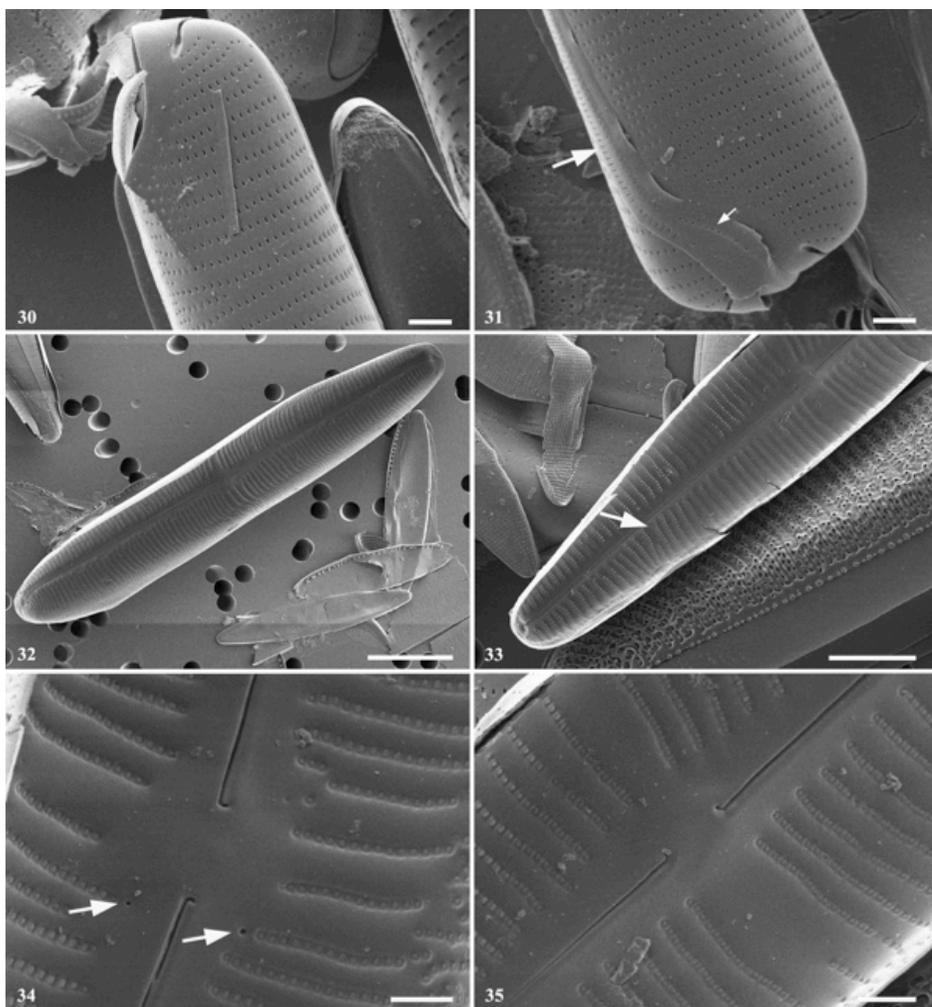
**Figures 2–19.** *Staurophora ouiangaensis* Rirongarti, Cocquyt, Paillès & Sylvestre *sp. nov.* LM, DIC. Valves and frustules from type material from Lake Jabou, Ouinanga Sérir, Chad, holotype slide BR4635. Figs 2-15. Valves views showing the size diminution series. Figs 16-19. Frustules in girdle views. The valve shown in Fig. 11 represents the holotype. Scale bar = 10  $\mu\text{m}$ .

**SEM observations (Figs 20–31):** —Frustule weakly twisted along the transapical axis (Figs 23, 24). Smooth transition between the valve face and the valve mantle. Striae uniseriate, 16–18 in 10  $\mu\text{m}$ , becoming somewhat denser, 22 striae in 10  $\mu\text{m}$ , near the apex, and continuous on the valve mantle. Striae weakly radiate throughout the largest part of the valve and becoming parallel near the apex. Voigt discordance sometimes very distinct (Fig. 21, arrow). On the valve mantle of large valves, an additional stria is present in between most of the striae. Striae composed of slightly transapically elongated areolae, about 45 in 10  $\mu\text{m}$ . Internally, areolae occluded by a hymen (Figs 30–31). Occasionally, a stria becomes biseriate near the axial area (Fig. 25, arrow). Axial area narrow, slightly widening towards the central area. Central area rectangular and of variable width, sometimes with a complete stauros (Fig. 22) but most often asymmetric and delimited by one to three striae. Shortened striae on the primary side longer than on the secondary side (Fig. 20); in the smallest valves sometimes not shortened at all (Fig. 25). Small isolated rounded areolae may be present in the central area on the secondary side (Fig. 25, arrows). Raphe straight, filiform. Central raphe endings externally straight, not enlarged (Fig. 25), internally bent towards the primary side, forming almost a right angle (Figs 30, 31). Externally, terminal raphe endings broadly curved towards the primary side and continuing on the valve mantle with a slightly enlarged fissure (Figs 20–22, 26); internally ending in a small helictoglossa (Figs. 28, 29). Two girdle bands present. The valvocopula ornamented with a single row of small slightly elongated poroids, about 55 in 10  $\mu\text{m}$ . (Figs 24, 27). The other band bears also one row of poroids which are distinctly elongated (Fig. 27).



**Figures 20–25.** *Staurophora ouiangaensis* Rirongarti, Cocquyt, Paillès & Sylvestre *sp. nov.*

SEM, from type material from Lake Jabou, Ouinanga Sérir, Chad, external views. Figs. 20–23. Valves views showing the uniseriate striae, the narrow axial area which is slightly widening towards the rectangular central area. Fig. 21. Valve with distinct Voight discordance (arrow). Figs 23, 24. weakly twisted frustules along the transapical axis. Fig. 25. Detail of the central area, and the uniseriate striae; rarely a stria is partly biseriate (arrow). Scale bar fig. 25 = 1  $\mu\text{m}$ , figs 20–24 = 10  $\mu\text{m}$ .



**Figures 26–31.** *Staurophora ouiangaensis* Rirongarti, Cocquyt, Paillès & Sylvestre *sp. nov.* SEM, from type material from Lake Jabou, Ouinanga Sérir, Chad. Figs 26–27. External views. Fig. 27. Detail of the valvocopula ornamented with a single row of small slightly elongated poroids and a girdle band with distinctly elongated poroids. Figs 28–31. Internal views. Fig. 29. Detail of the Voight discordance (arrow) and small helictoglossa at the raphe ending near the pole. Figs 30–31. Detail of the central raphe endings bent towards the primary side, the areolae occluded by a hymen, and some small isolated areolae (arrows). Scale bar figs 26–27, 30–31 = 1  $\mu\text{m}$ , 28–29 = 5  $\mu\text{m}$ .

## Discussion

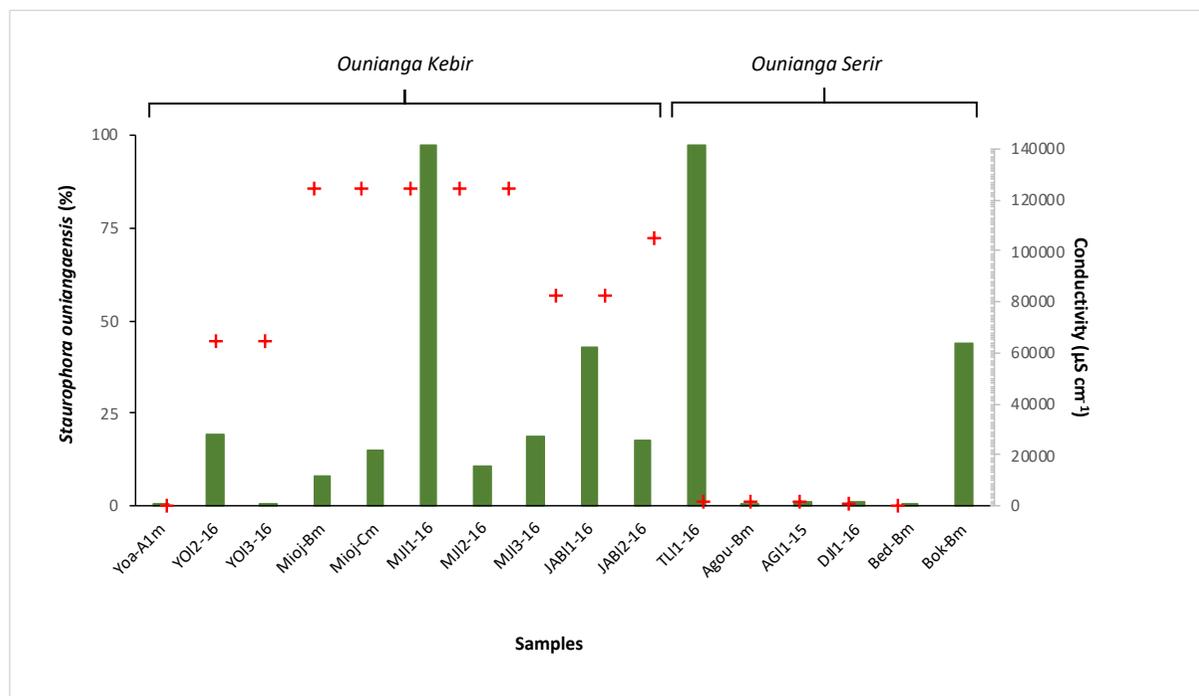
The valves of the new species resemble very well the valves of *Cymbella obtusa* Gregory (1856: 5) as depicted by Round (1961b). Based on Round's drawing and assuming a magnification of 1000x, we found valves length of 22–43  $\mu\text{m}$ , valve width of 7–8.5  $\mu\text{m}$  and 11–14 striae in 10  $\mu\text{m}$  mid-valve, becoming somewhat denser near the poles to (12) 14–16 striae in 10  $\mu\text{m}$ . However, the valves represented by Round's drawings (Round 1961b) do not belong to *Cymbella obtusa*. Gregory (1856, p. 5, pl. 1 fig. 19) described *Cymbella obtusa* from Lochleven, Banffshire, Lanarkshire, Argyllshire, etc. in Scotland, United Kingdom. The taxon is regarded as a synonym of *Cymbella aequalis* W.Smith (in Greville 1855: 255) (Guiry & Guiry 2020), and is currently accepted as *Kurtkammeria aequalis* (W.Smith) Bahls (2015: 173). *Cymbella aequalis* was also described from Scotland, namely from Ben-na-Muic-Dhui, Braemer. The girdle views as depicted by Round (1961b, Figs 44, 46) have the typical form of representatives of the genus *Staurophora* (Cocquyt 2004). Moreover, the valve outline of *Cymbella obtusa* is totally different from the valves observed during our investigation and from the drawing in Round (1961b). On the other hand, *Cymbella obtusa*, of which valves are somewhat resembling the valves in studied material from Chad, was reported from Bornholm in Denmark by Foged (1982, Pl. 28 fig. 5). Differences can be noted in the striation which is much coarser (12–13 striae in 10  $\mu\text{m}$ ) in *Cymbella obtusa* compared to the 16–19 striae in 10  $\mu\text{m}$  in *Staurophora ouiangaensis* (Table 2).

	<i>Staurophora ouiangaensis</i>	<i>Staurophora vilamae</i>	<i>Staurophora caljonii</i>
Valve length (µm)	20.4–59.5	37.1–48.3	17.5–39.4
Valve width (µm)	4.3–8.6 (10.5)	9.4–11.5	4.4–7.5
Valves	Poles slightly rostrate Weakly twisted transapically	Poles rounded, subrostrate to rostrate	Slightly protracted near poles Twisted transapically
Central area	Variable, asymmetric, expanded to the valve face edge on the secondary side Absent with a single median more widely spaced stria, if present variable width with one to three more widely spaced striae of variable length	Highly variable, slightly widened Few irregularly shortened and more spaced striae	Small, reaching the valve margins Sometimes 1–2(3) shortened striae
Axial area	Narrow, somewhat enlarged near the central nodulus	Linear, very narrow	Enlarged near the central nodulus
Striae in 10 µm	Weakly radiate, convergent towards the poles	Weakly radiate, slightly denser on the mantle	Straight to slightly radiate, straight near the poles
mid valve	(15) 16–19	16–31	16–21
near poles	(17) 18–24		
Raphe	Straight filiform Central endings weakly enlarged Terminal endings deflected to the same direction	Straight filiform* Central endings weakly enlarged* Terminal endings deflected to the same direction*	Straight filiform Central endings somewhat enlarged, laterally hooked Terminal endings deflected to the same direction
Areolae in 10 µm	45–50 Slightly transapically elongated	50–55 Tiny and punctate	65–70 Laterally enlarged
Literature	this study	Maidana et al. 2009	Cocquyt 2004

**Table 2.** Comparison of some morphological features in *Staurophora ouiangaensis spec. nov.* and morphologically related taxa according to this study and literature data.

The characteristics given by Desianti *et al.* (2015) in their argumentation for the transfer of *Navicula agmastrata* Hohn & Helleman (1966: 125) to *Staurophora*, e.g., valve length and width, radiate striae composed of circular to transapically elongated areolae and an expanded central area into a transverse fascia, are all presented in our new species. Moreover, the frustules are slightly twisted along the transapical axis, as was also observed in *Staurophora caljonii* (Cocquyt 2004).

Of the fifteen *Staurophora* species, only six have been reported from Africa (Guiry & Guiry 2020): *S. amphioxys* (W. Gregory) D.G. Mann as *Stauroneis amphioxys* W. Gregory from Gambia (Foged 1986); *S. salina* (W. Smith) Mereschkowsky as *Stauroneis salina* W. Smith from Gambia (Foged 1986) and South Africa (Giffen 1967); *S. soodensis* (Krasske) Bahls as *Navicula soodensis* Krasske from Gambia (Foged 1986) and South Africa (Giffen 1967); *S. tackei* (Hustedt) Bahls as *Stauroneis palustris* Hustedt from Sudan (Reinhold 1937); *S. wislouchii* (Poretzsky & Anisimoca) D.G. Mann from Ghana (Smith *et al.* 2015) and as *Stauroneis wislouchii* from Ghana (Foged 1966). *S. caljonii* is the only species which has actually not been reported from other sites than its type locality (Lake Sonachi) in Kenya (Cocquyt 2004).



**Figure 32.** Relative abundance (%) of *Staurophora ouiangaensis* sp. nov. in Lakes Yoa (Yoa, YO), Mioji (Mioj), Jabou (JAB), Teli (TL), Agouta (Agou, AG), Djara (DJ), Bedrim (Bed) Bokou (Bok).

### Representativeness in present and past Ounianga Lakes

Today, *Staurophora ouiangaensis* is observed in lakes from Ounianga Kebir and Serir (Figure 32). From the forty-three samples collected in all lakes from the system, *S. ouiangaensis* is present in sixteen samples (Figure 32). It is well represented (> 40%) in Lakes Mioji, Jabou, Teli and Bokou (Figure 32). In Lake Teli, frustule preservation of *S. ouiangaensis* is poor and shows signs of dissolution, whereas in the others lakes, the frustules are well preserved. In these lakes, *S. ouiangaensis* is mainly associated with *Gogorevia exilis* (Kützing) Kulikovskiy & Kociolek (in Kulikovskiy *et al.* 2020: 1610 (= *Achnantheidium exiguum* (Grunow) Czarnecki (1994:157)), *Navicula globulifera* Hustedt (1927: 164), *Neidium dubium* (Ehrenberg) Cleve (1894: 70), *Nitzschia pusilla* Grunow (1862: 579), *Encyonopsis subminuta* Krammer & E. Reichardt (in Krammer 1997: 96), *Aulacoseira granulata* (Ehrenberg) Simonsen (1979: 58), *Anomoeoneis vitrea* (Grunow) R.Ross (in Patrick & Reimer 1966: 380), *A. sphaerophora* Pfitzer (1871: 77), *Mastogloia smithii* Thwaites ex W.Smith 1856: 65), *Gomphonema gracile* Ehrenberg (1838: 217), *Ulnaria ulna* (Nitzsch) Compère (2001: 100) and *Navicula radiosa* Kützing (1844: 91). *Staurophora ouiangaensis* is also observed in Lake Yoa between few isolated valves (<1%) and 19% of the assemblages. It is mainly associated with *Rhopalodia acuminata* Krammer (in Lange-

Bertalot & Krammer 1987: 75), *Nitzschia pusilla* and *Anomoeoneis sphaerophora*. In Lakes Bedrim, Agouta and Djara, only a few valves (<1%) were observed.

From Ounianga lake district, Lakes Teli and Mioji are the most saline lakes, with conductivity measured at 124,000  $\mu\text{S}\cdot\text{cm}^{-1}$  and 105,100  $\mu\text{S}\cdot\text{cm}^{-1}$  respectively (Table 1). Lakes Jabou and Yoa present lower conductivity at 82,700  $\mu\text{S}\cdot\text{cm}^{-1}$  and 64,900  $\mu\text{S}\cdot\text{cm}^{-1}$  respectively, whereas Lake Bokou is the freshest lake at 326  $\mu\text{S}\cdot\text{cm}^{-1}$  (except spring water conductivity for instance sample Yoa-A1m, Table 1). This suggests that this species has a wide tolerance to water conductivity. *Staurophora ouiangaensis* is observed in the surface sediments of all lakes. In Lakes Yoa, Mioji, Agouta, Bedrim and Bokou, *the new taxon* is observed in different habitats, and in samples collected on macrophyths, and in Lake Bokou its was present in the water column (Table 1).

Based on the fourty three samples collected in all lakes from Ounianga, a transfer function was developed based on the relationships between the distribution of diatom species and environmental parameters using multivariate analysis (Remadji et al., in review). Conductivity is the variable explaining most of the variance in the diatom flora, allowing to reconstruct for each species their optimum and tolerance towards conductivity. For *Staurophora ouiangaensis*, its inferred optimum is estimated at  $93,600 \pm 6690 \mu\text{S}\cdot\text{cm}^{-1}$ .

This species was also observed in the fossil record. Fossil diatom analysis conducted on four cores drilled in Lakes Yoa, Teli, Edem and Agouta (Kropelin et al., 2008; Van der Meeren et al., 2019) revealed that *Staurophora ouiangaensis* is only present in the upper half meter of the core in Lake Teli. In this section the frustules are progressively dissolved downwards. Thereafter, from 0.6 m up to the end of the core (3.8 m) *S. ouiangaensis* is absent. It is probably completely dissolved due to increased salinity.

The Ounianga region in Chad, being unique by lying in the widest and hottest desert in the world, preserved several lakes because of groundwater discharge from nubian sandstone. The lakes span a wide range of conductivity from fresh to hypersaline waters. Investigations in their modern diatom content (water column and surface sediments) evidenced a new species, described as *Staurophora ouiangaensis*. This species is observed in a wide range of conductivity today (326 to 124,000  $\mu\text{S}\cdot\text{cm}^{-1}$ ), whereas during the past, it is up to no preserved only in one of the highest saline lake. Since not all Ounianga lakes have been drilled, it is quite possible that *Staurophora ouiangaensis* can also be observed elsewhere in these unique aquatic environments.

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